
Sensor Webs for Autonomous Mission Operations
SWAMO
Earth Science Technology Conference 2008
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SENTAR
NASA
WVHTC FOUNDATION

Talking Points

- Development Team
- Background
- SWAMO Architecture
- SWAMO Use Cases
- Acknowledgements and Questions

Development Team

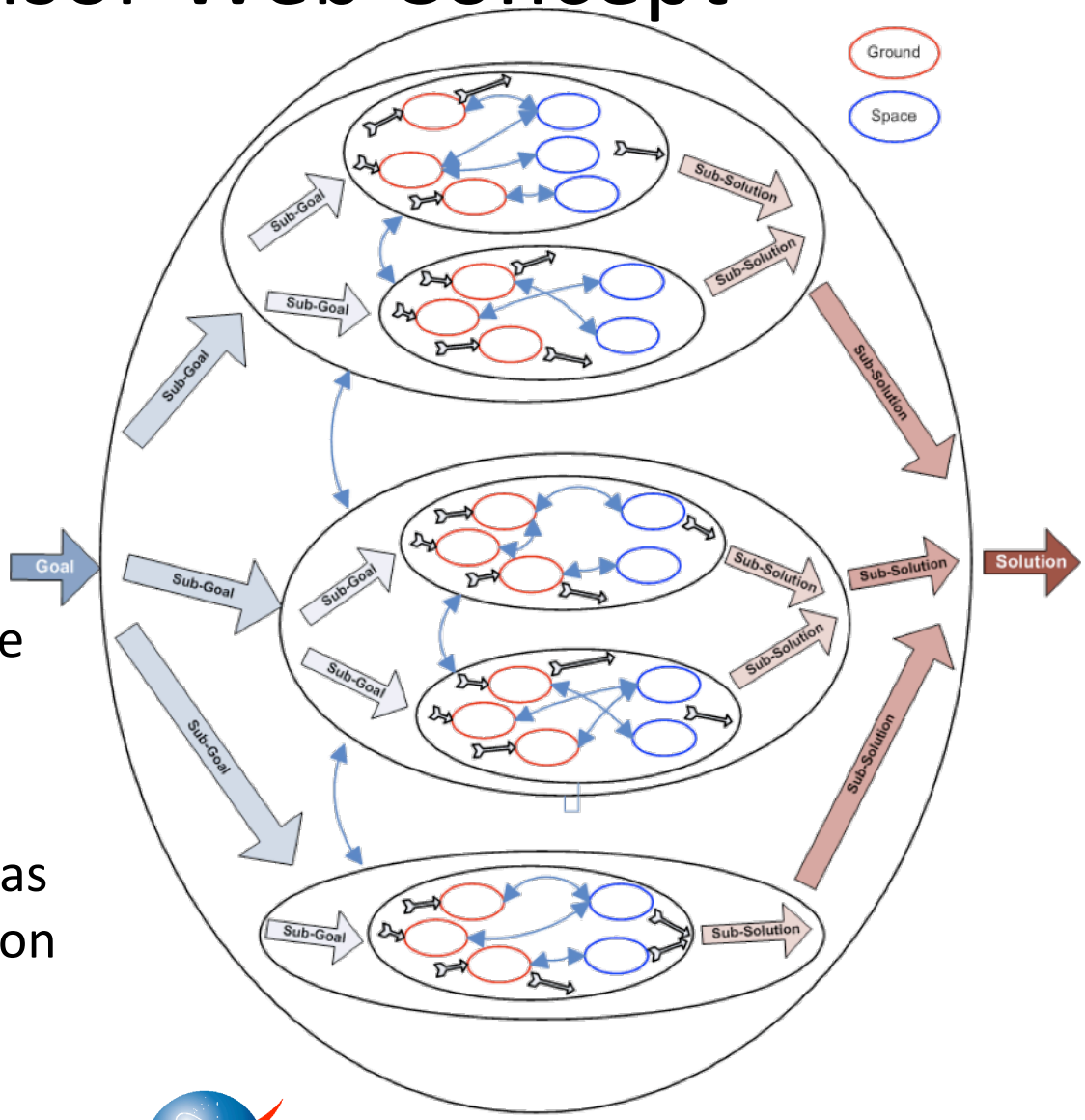
- West Virginia High Technology Consortium Foundation (WVHTCF)
  - Ken Witt (PI)
  - Jason Stanley (Development Lead)
  - David Smithbauer (Developer)
- NASA GSFC
  - Dan Mandl (CO-I)
  - Vuong Ly (Developer)
- Sentar Inc.
  - Al Underbrink (CO-I)
  - Mike Metheny (Developer)

Coming up to speed…

BACKGROUND

Our Sensor Web Concept

- Input high level goal
- High level systems break down the goal into sub -goals
- Disseminate sub-goals to lower level systems
- Low level systems provide sub-goal solution
- Sub-solutions are recombined and output as the high level goal solution



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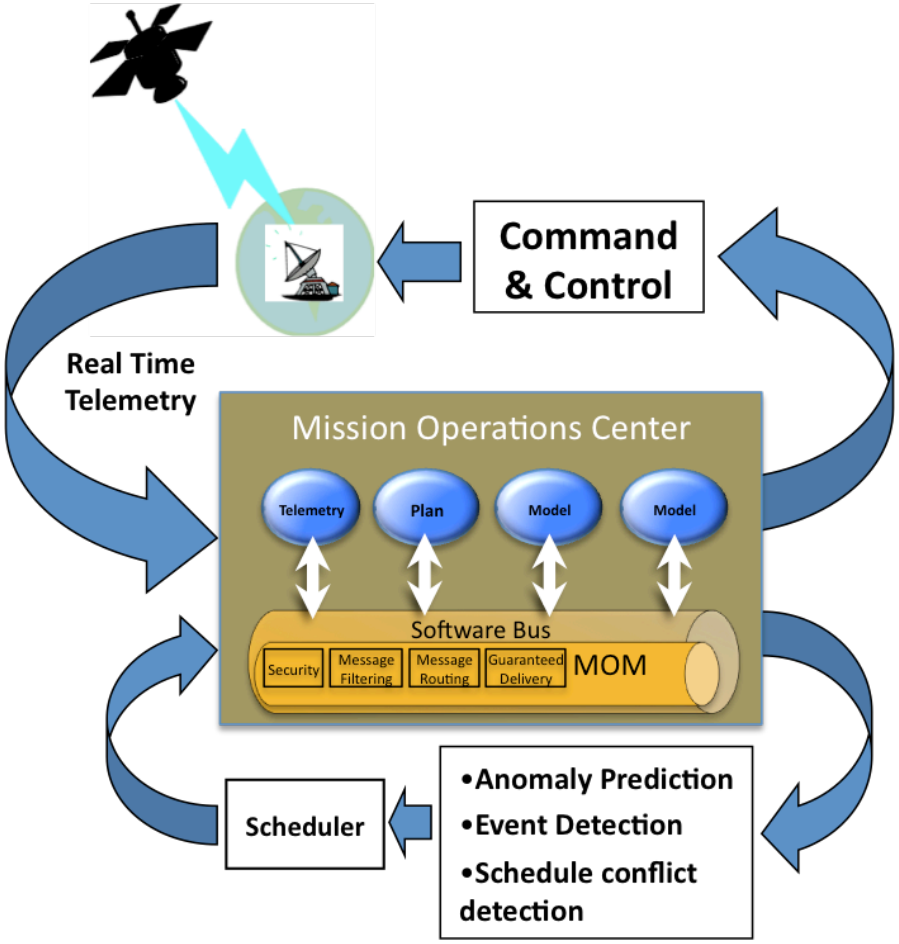
Enabling Technologies

- Model Based Operations (MBO)
  - Modeling and simulation framework
  - Model spacecraft subsystems and processes
  - Models update with live telemetry
  - Model output used to updated schedule
- Software Bus
  - Message Oriented Middleware (MOM)
  - Publish/Subscribe
  - Standard set of defined messages (language)
  - Single application interface



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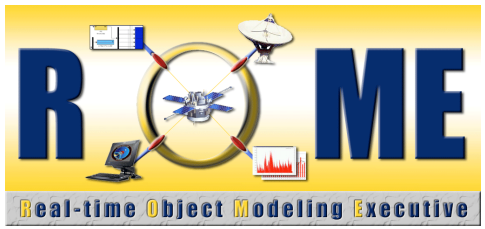
Previous Experience

- Real-time Object Modeling Executive (ROME)
  - MBO implementation for Space Technology 5 (ST5) Mission
- Mission Details
  - 3 satellite constellation of nanosats to study the magnetosphere
  - Launched in March 2006
  - 1 week “lights-out” operation in May 2006
  - Model Based Operations
    - Solid State Recorder, Power, RF Link Margin
  - Models initialized and maintained from telemetry
  - 3 day short term in-situ and 28 day offline model simulations



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Taking it to the next level….

SWAMO ARCHITECTURE

What Does SWAMO Do?

"The goal of SWAMO is to shift the control of spacecraft missions to a collaborative, distributed set of intelligent agents verses a centrally controlled architecture. The network of intelligent agents will reduce management requirements by utilizing model-based system prediction and autonomic model/agent collaboration."

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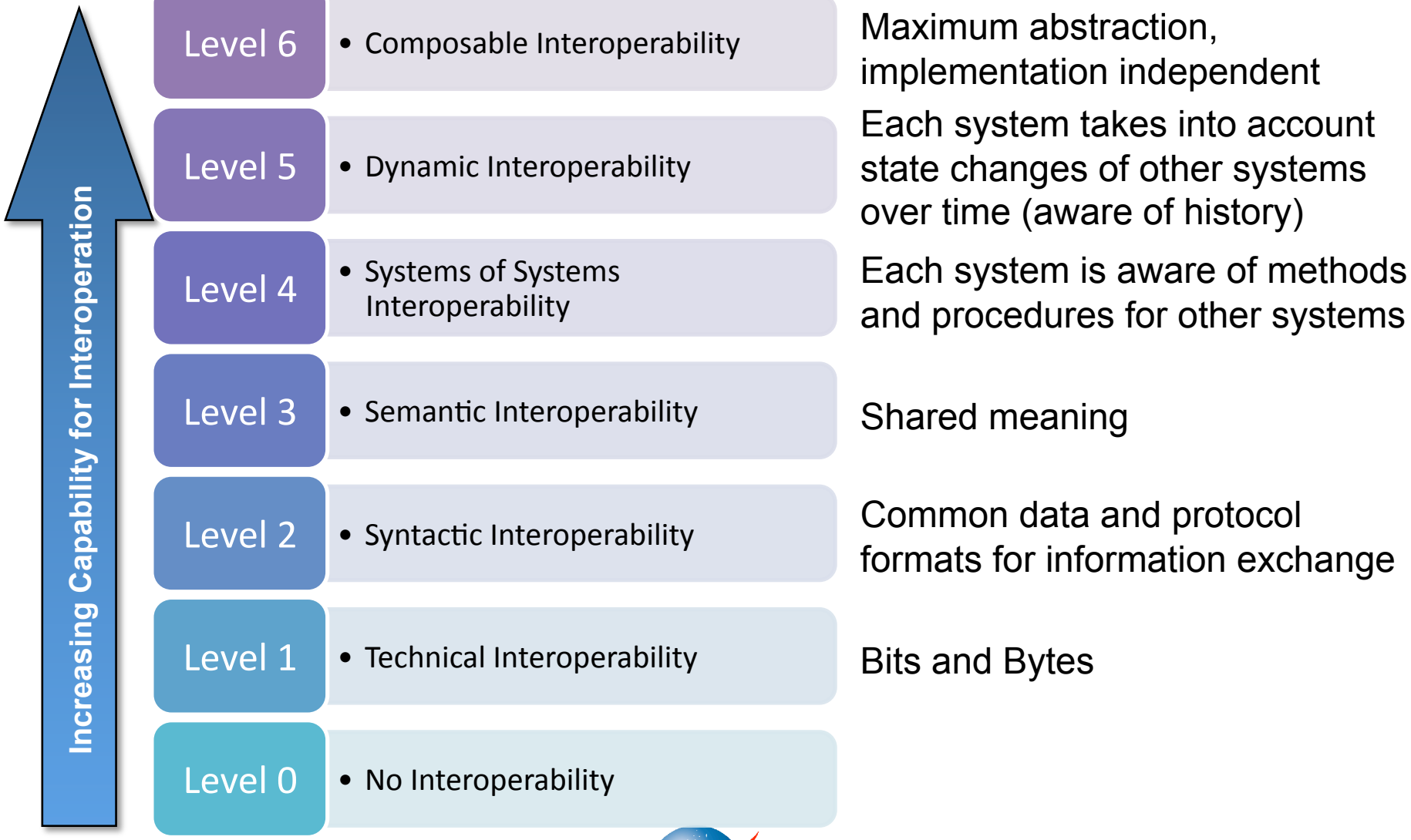
Composability and Levels of Interoperability



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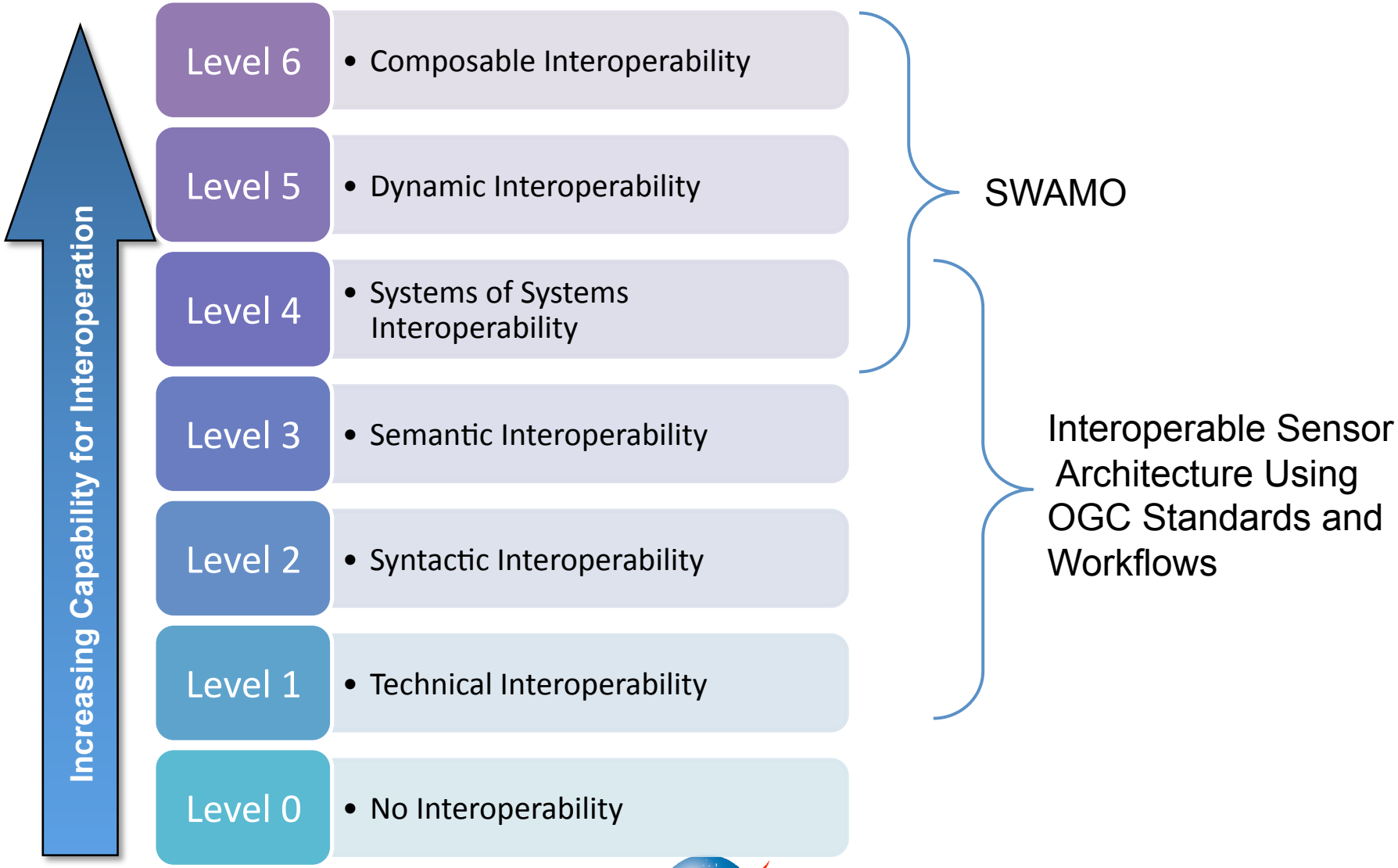
Where SWAMO Fits



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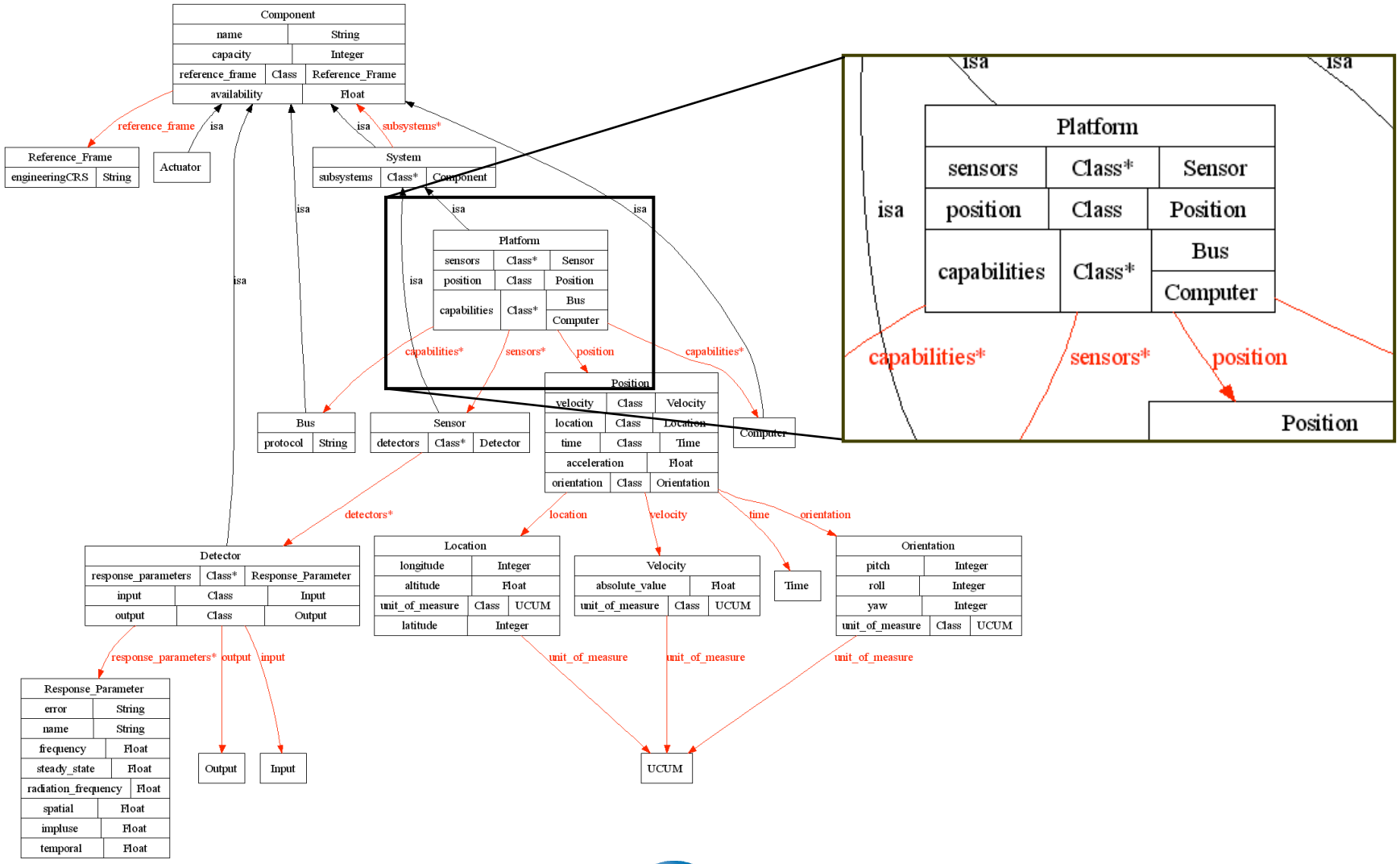
SWAMO Ontology

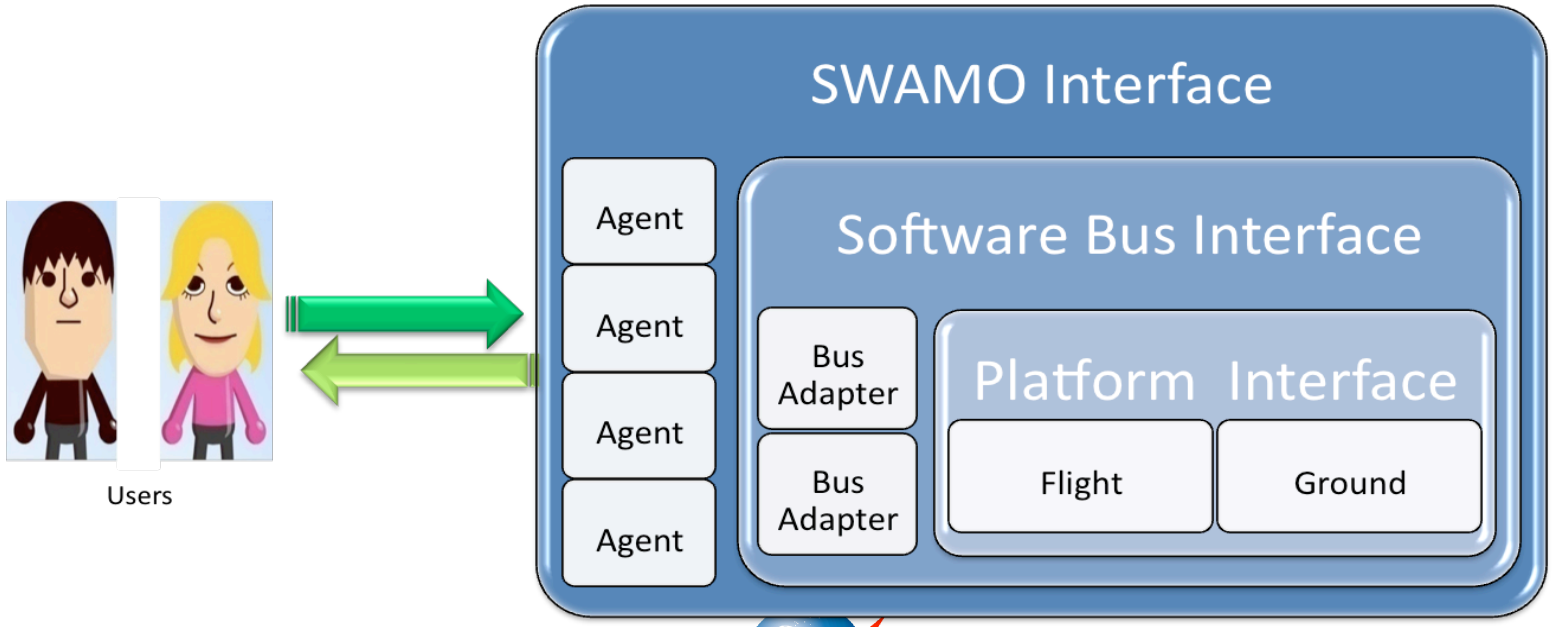
- Used by SWAMO intelligent agents to support autonomous operations
  - Describes Sensor Web application domain for science experiment planning, monitoring, and controlling
  - Describes autonomous agents for system-wide resource sharing, distributed decision making, and autonomic operations
- Ontology represents semantics of the Sensor Web domain concepts and their relationships
  - Physical and logical structure and descriptions
  - Platforms, sensing devices, performance characteristics, etc.
  - Experiment processes and chains, process models, required parameters, process interconnections, etc.
  - Intelligent agent capabilities, experiment schedules and tasks, platform workloads, etc.
- Consistent with SensorML and OWL models

Ontology using Frames Representation



SWAMO High Level Architecture

- SWAMO acts as a 'Black Box' - users and systems hidden from implementation details
- SWAMO encapsulates all component interfaces (Agents, Software Bus, Bus Adapters, Platforms, and Models)
- Users submit high level goals, SWAMO utilizes available components and resources to return a result



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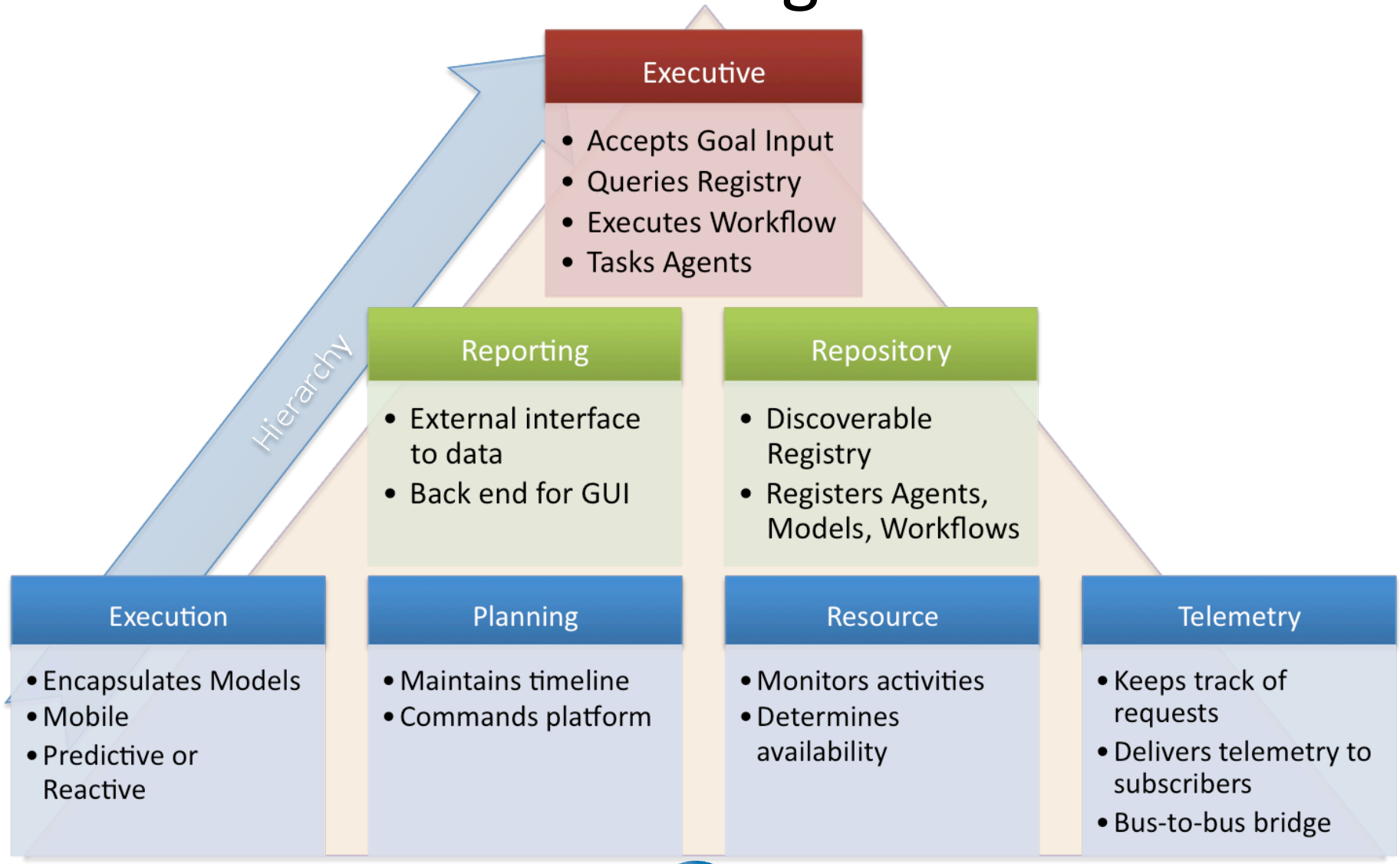
SWAMO Agents



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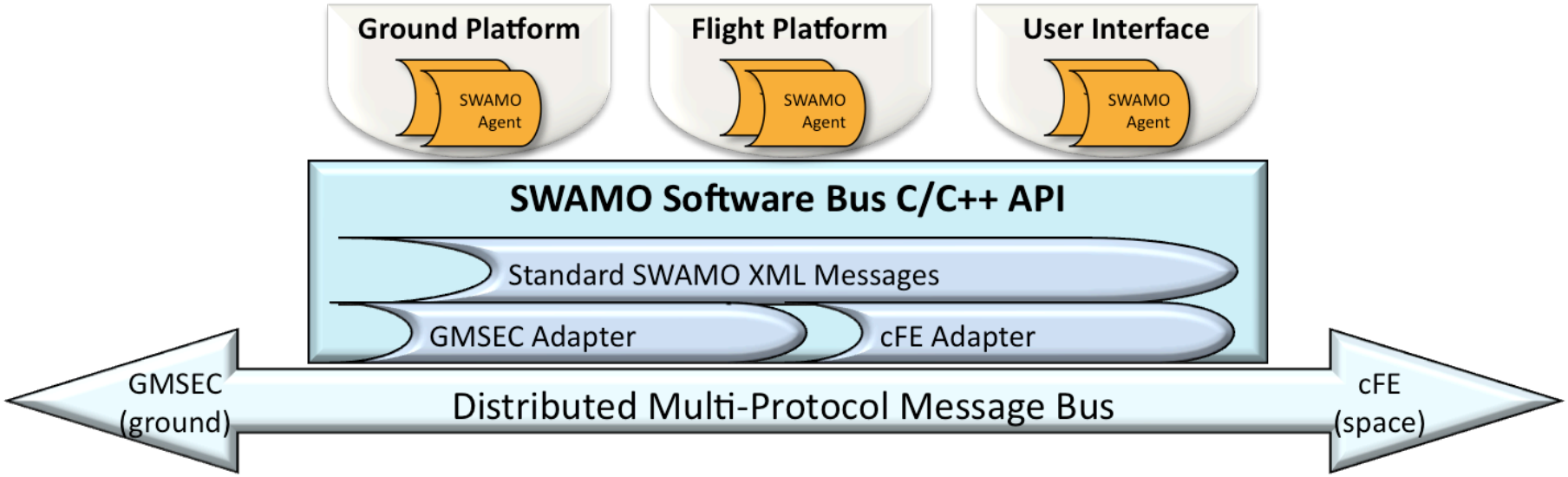
SWAMO Software Bus



- Provides messaging interface for all SWAMO agents and systems
- Encapsulates standard ground and flight based bus APIs
  - Goddard Mission Services Evolution Center (GMSEC) ground bus interface
  - core Flight Executive / Core Flight System (cFE/CFS) flight bus interface
- Flexible to support other additional bus adapters
- C/C++ Implementation
- Platform independent (Linux, Windows, VxWorks)

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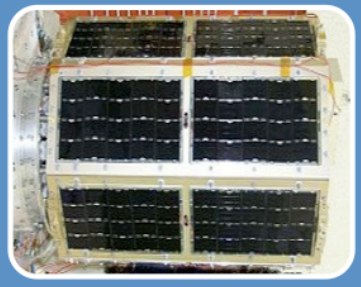
SWAMO Flight/Demo Platforms

ST5 FlatSat

- ST5 flight hardware used during design and testing of the spacecraft
- Provides a telemetry stream
- Simulated science instrument (magnetometer)
- Accepts spacecraft commands

PowerPC Flight Hardware Simulators

- Runs VxWorks OS
- Runs cFE flight software bus
- Provides flight platform test bed for agents



MidSTAR-1

- Built by United States Naval Academy Small Satellite Program (SSP)
- Launched on March 8, 2007
- IP in space connection
- Linux based, on orbit test platform

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SWAMO Models

Name	Description	Maturity
MidSTAR-1 Power	• Reactive Model • State machine • Monitors battery voltage levels • Adjusts load levels to regulate voltage	Gen 2
ST5 Power	• Built by engineers during spacecraft design • Predicts voltage levels based on solar illumination • Used by ROME on ST5	Complete
ST5 RF Link Margin	• Built by ST-5 interns during mission operations testing • Predicts link margin levels for upcoming contacts • Used by ROME on ST5	Complete
ST5 Memory (SSR)	• Built by WVHTCF during mission operations design • Predict memory threshold violations • Used by ROME on ST5	Complete

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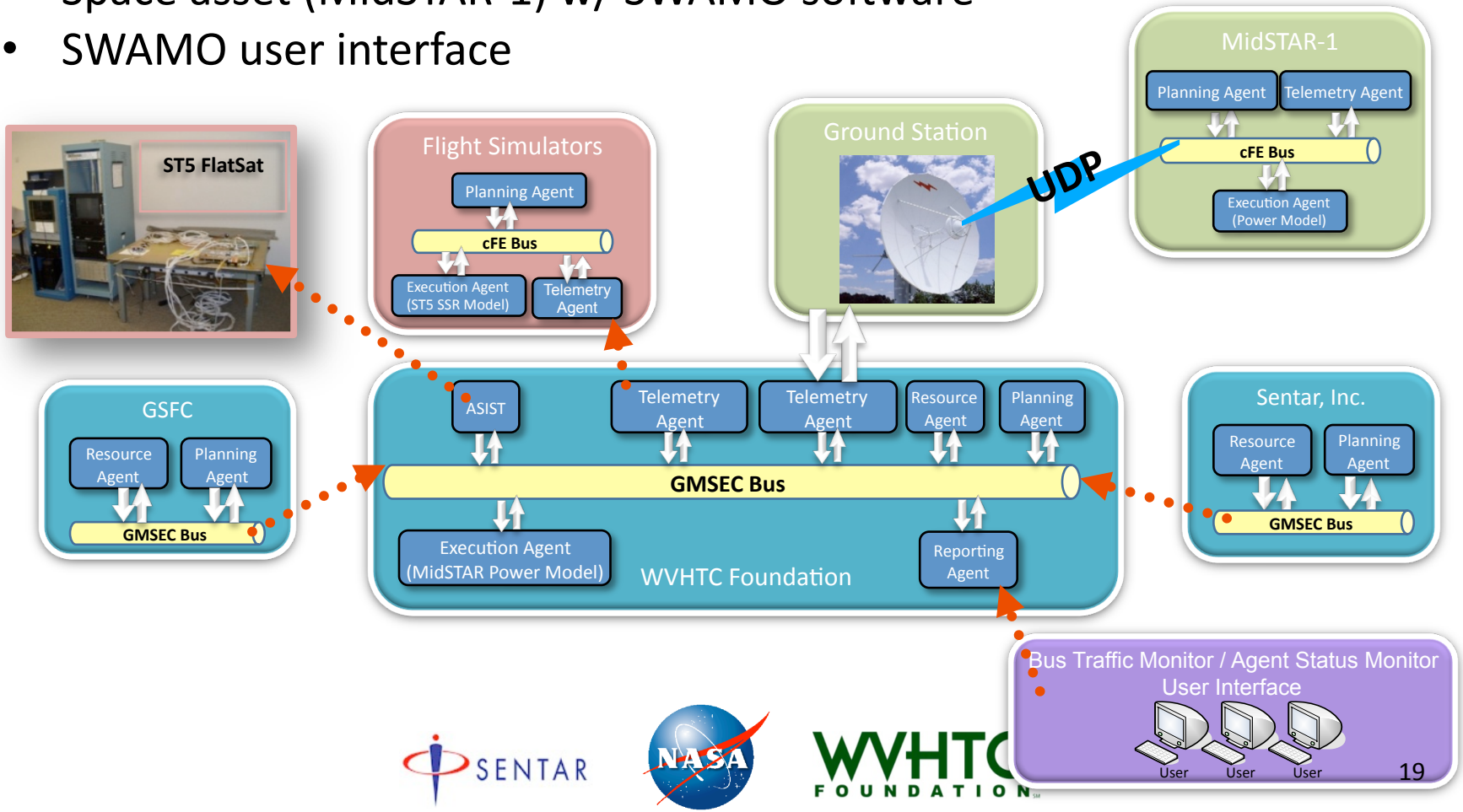
Current Development Topology

- Simulated distributed mission operations centers
- Spacecraft flight simulators and ST5 Flatsat from mission
- Space asset (MidSTAR-1) w/ SWAMO software
- SWAMO user interface



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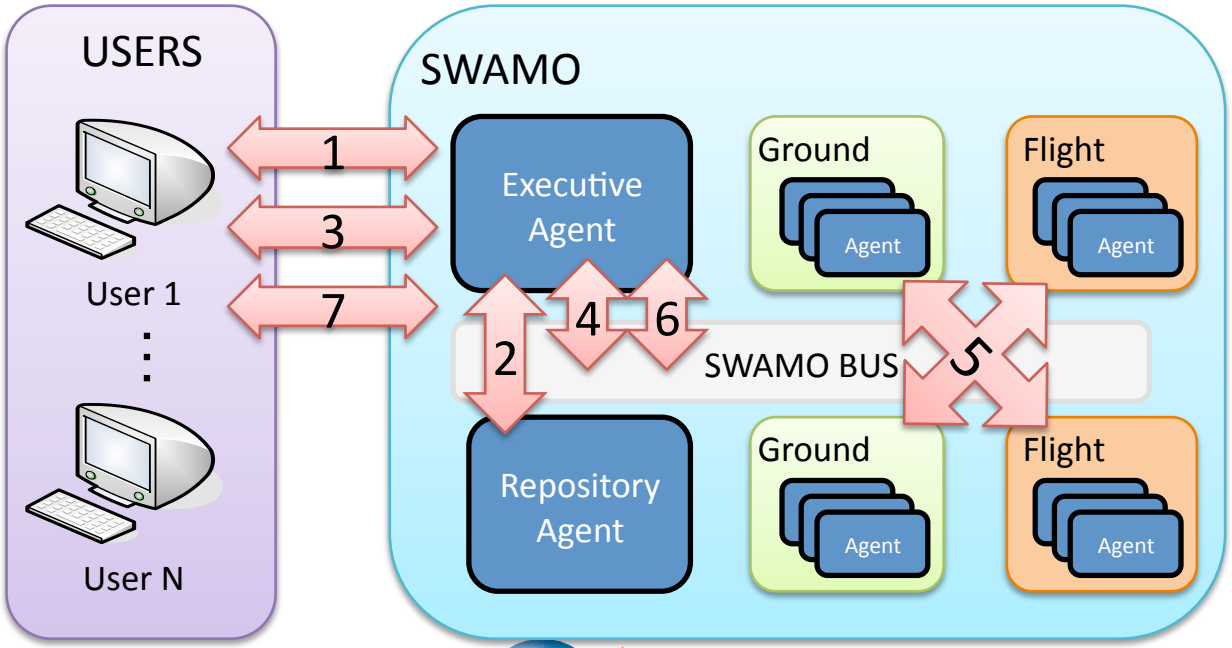
Where the rubber meets the road…

SWAMO USE CASES

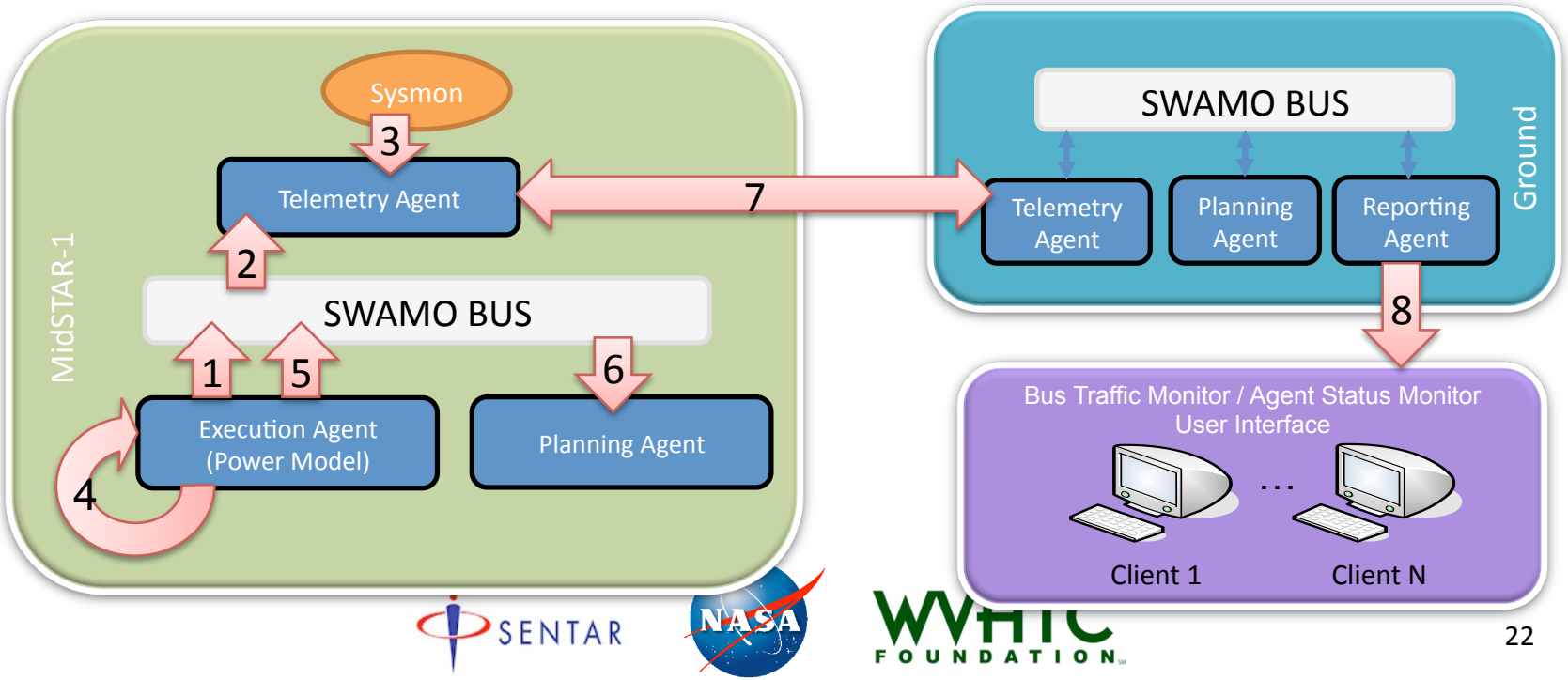
Project Goal Use Case

1) User requests a science goal
2) Executive Agent queries Repository (workflow, agents, models)
3) Executive Agent notifies user of goal feasibility and user accepts
4) Executive Agent executes goal workflow by assigning tasks
5) Agents collaborate to achieve assigned tasks
6) Executive Agent collects agent tasking results
7) Science goal solution is presented to user



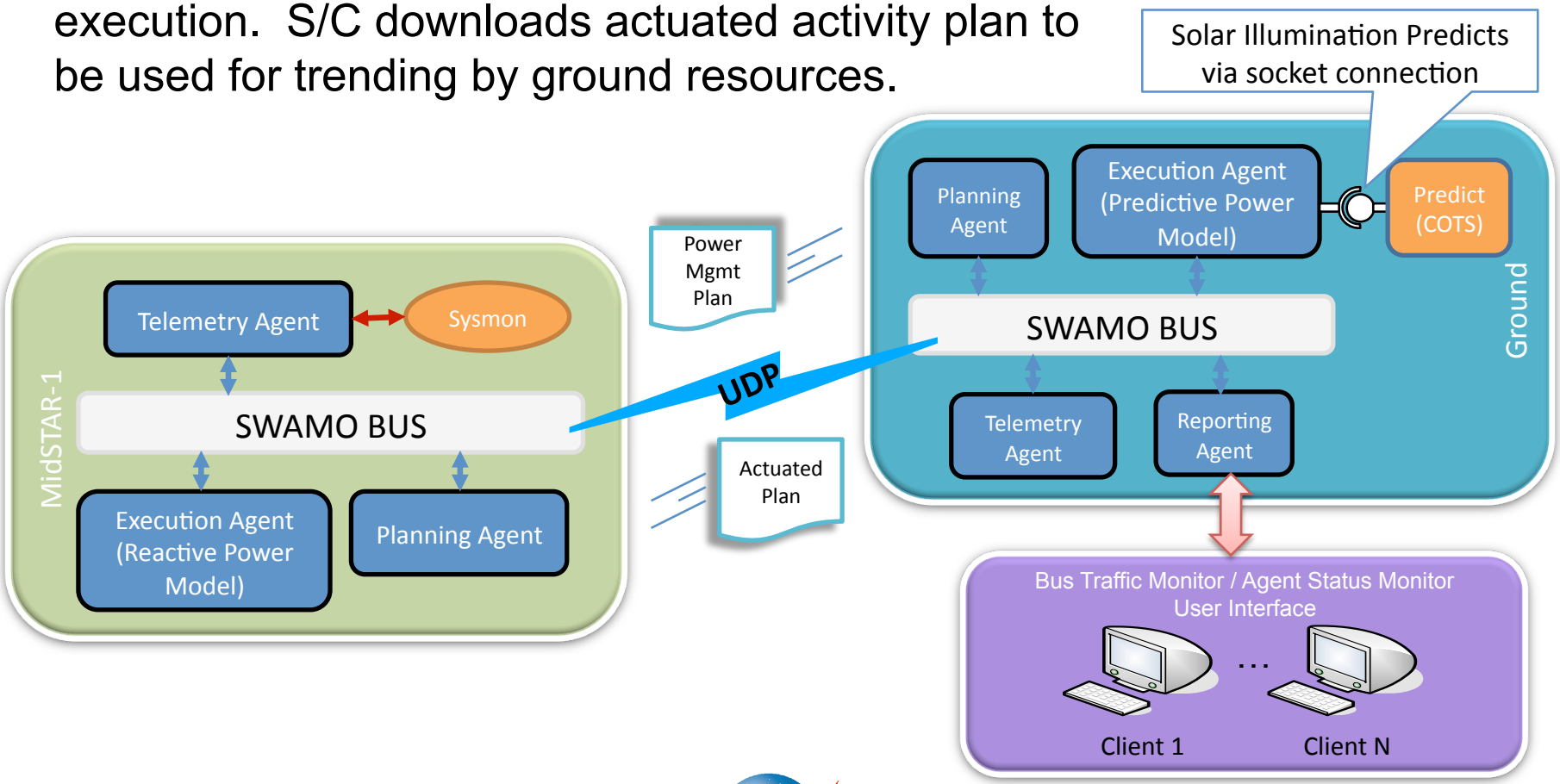
Implemented MidSTAR-1 Use Case

1) Execution Agent requests power model data
2) Telemetry Agent receives request and adds agents to listeners
3) Telemetry Agent receives telemetry data and publishes to listeners
4) Power model constantly monitoring state from telemetry
5) Execution Agent publishes Power model events
6) Planning Agent receives “command” events and inserts into system queue
7) Bus-to-bus bridge constants transfers SWAMO data
8) Reporting Agents report SWAMO data to UI subscribers



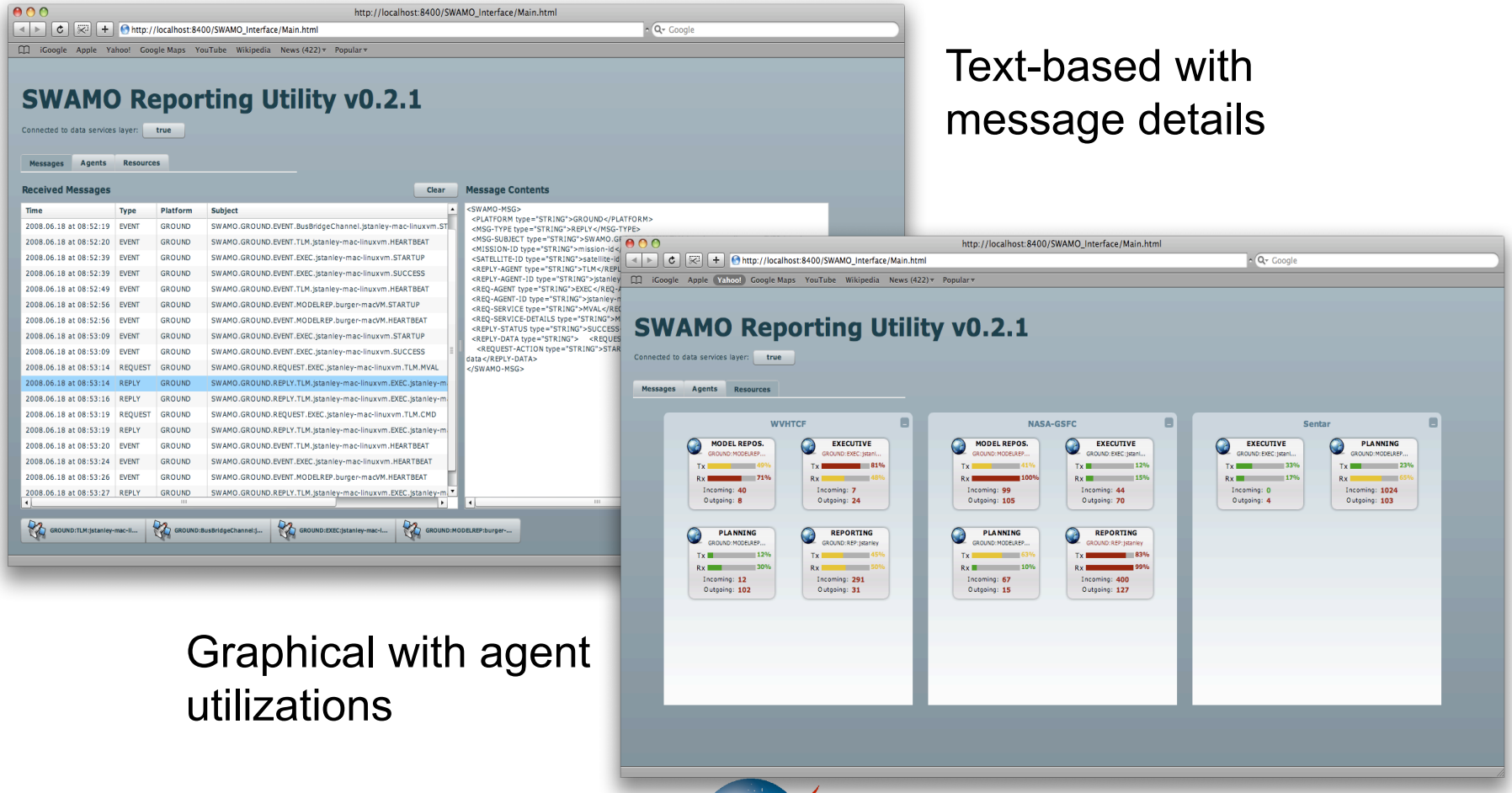
Current Development Use Case

Utilize solar illumination predictions to generate a plan for power management and upload to S/C for execution. S/C downloads actuated activity plan to be used for trending by ground resources.



SWAMO User Interface

Flash-based web interface



Text-based with message details

Graphical with agent utilizations

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Leveraging Standards

- Working with Dr. Mike Botts on SensorML
  - Open Geospatial Consortium standard
- Participated in OWS-5 Demonstration
  - Developed 3 process chains
    - Flood water classifiers for EO-1 Hyperion data
  - Developed initial Workflow Chaining Service (WfCS) as classifier repository and remote SensorML process chain execution engine
    - Capable of being triggered as part of larger workflow
    - Utilizes Sensor Observation Service
    - Stores completed data products for retrieval

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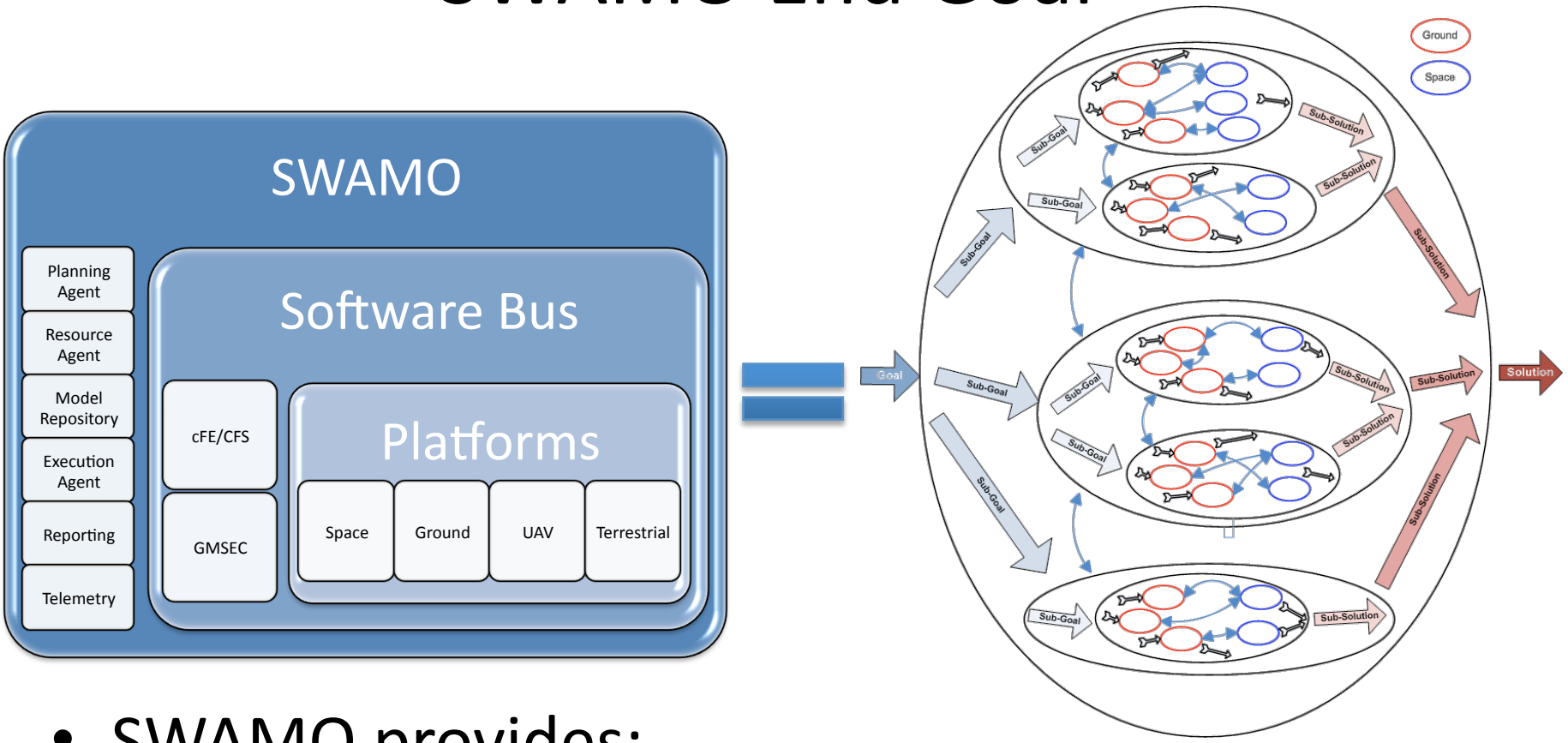
SWAMO End Goal



- SWAMO provides:
  - Autonomous spacecraft management
  - Solutions to high level science goals

SWAMO Benefits/Justification

- SWAMO's multi-agent system architecture provides several benefits over traditional systems:
  - ***Faster problem solving*** through parallelism
  - ***Decreased bandwidth*** consumption through partial data transmissions including only agent specific information
  - ***Greater flexibility*** of system through dynamically pairing necessary agents in ad-hoc fashion to solve specific problems
  - ***Increased reliability*** via graceful failover of agents and dynamic recovery

Acknowledgements

- ESTO
  - Steve Smith, Karen Moe, Vicki Oxenham
- MidSTAR
  - Keith Hogie, Ed Criscuolo : MidSTAR Operators
  - Dr. Billy Smith : US Naval Academy Small Satellite Program Director

QUESTIONS ?

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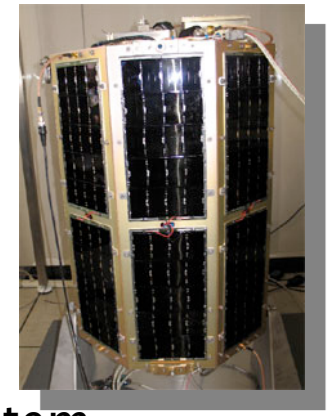
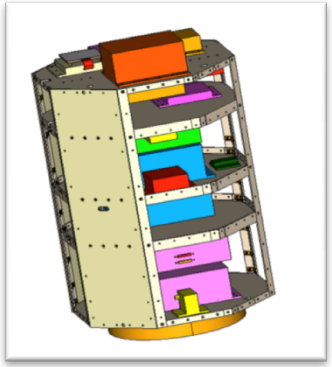
BACKUP SLIDES

MidSTAR



Midshipman Space Technology Applications Research

- US Naval Academy Small Satellite Program effort launched in March 2007
- General-purpose satellite bus with Linux operating system
- IP-in-space communication system
- Low-cost program launched through the DoD Space Test Program – Zero budget at this point
- MidSTAR is a single spacecraft under the command and control of a single satellite ground station at the US Naval Academy
- Operators (Keith Hogie and Ed Criscuolo) maintain satellite from Goddard Space Flight Center



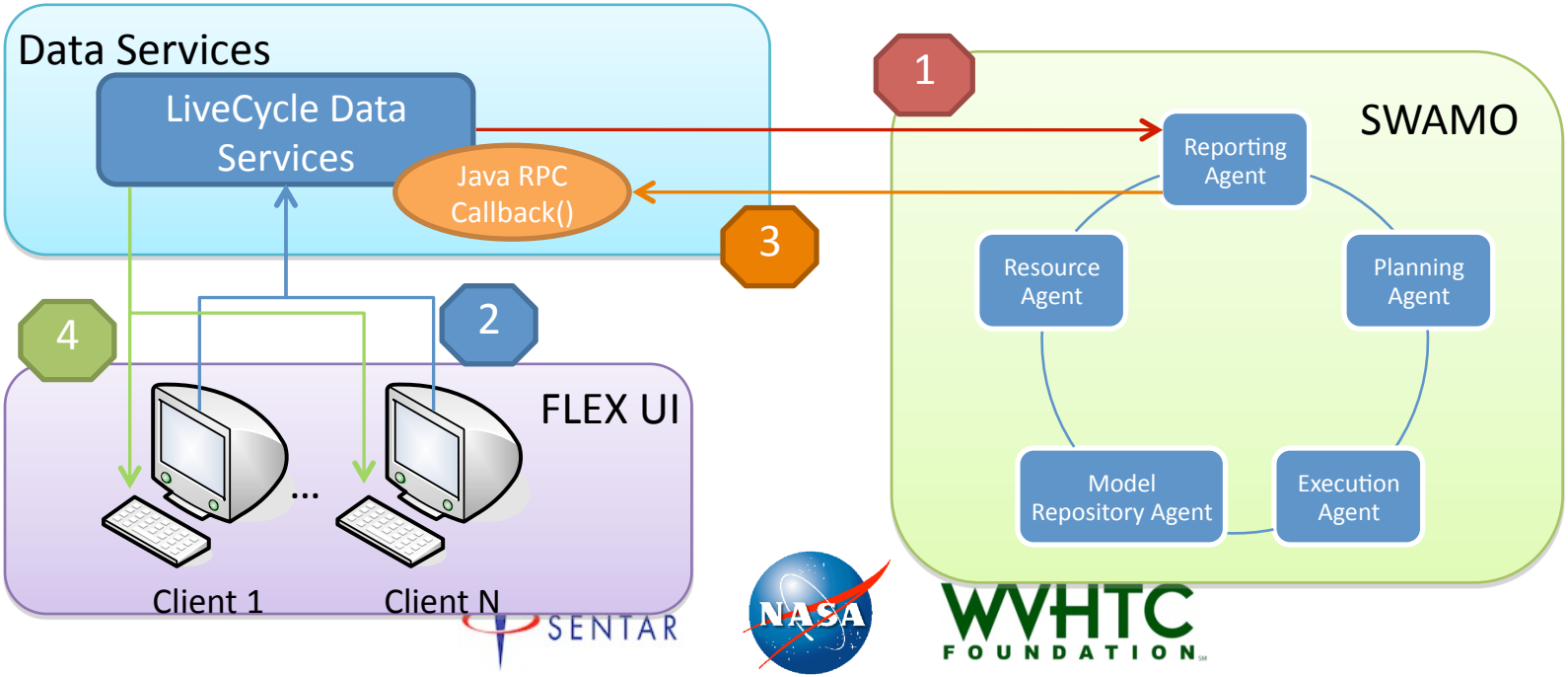
SWAMO Agents

Agent	Description	Maturity
Execution	• Encapsulates models for initialization, execution, and packaging model data • Can be mobile, allowing for the transition of the model's execution state • Can execute "predictive" and "reactive" models	Gen 2
Reporting	• Provides status and health information about all SWAMO assets • SWAMO data access via XML-RPC interface to the SWAMO bus	Gen 1
Planning	• Creates, maintains, and distributes a command timeline for the assigned platform • Commands platform	Gen 2
Resource	• Determines and tracks resource availability for the assigned platform • Monitors data transfer requests and schedules transfer between platforms	Gen 2
Telemetry	• Provides telemetry data to all agents for assigned mission • Handle requests and distributes data from live telemetry stream • Provides flight to ground bus-to-bus bridge connection	Gen 2
Executive	• Responsible for high level goal decomposition, agent instantiation, task dissemination, and workflow execution	Prototype
Repository	• Provides discoverable registry services for outside interfaces and high level agents • Registries include Agents, Models, Simulation Data, and Workflow descriptions	Prototype

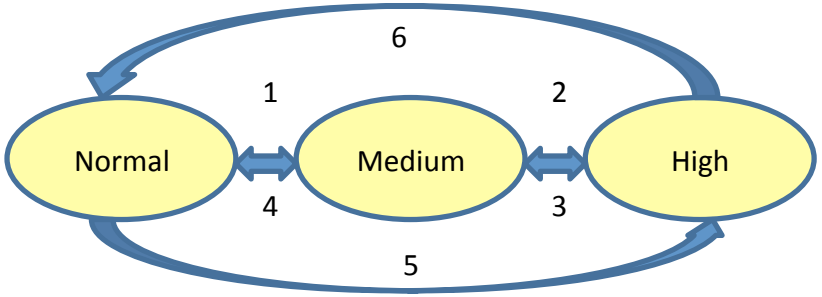
User Interface

1. Adobe's LiveCycle Data Services (LCDS) registers callback URL and function (Java RPC) with SWAMO Agent.
2. One or more clients register with LCDS Server by creating and subscribing to a channel.
3. As messages are passed across the SWAMO bus, they are routed through the XML-RPC agent to the LCDS Server.
4. The messages are then displayed in real-time on the client machines' FLEX user interface.

FLEX is an Adobe User Interface platform based on Adobe Flash, utilizing standard web protocols



MidSTAR Power Model

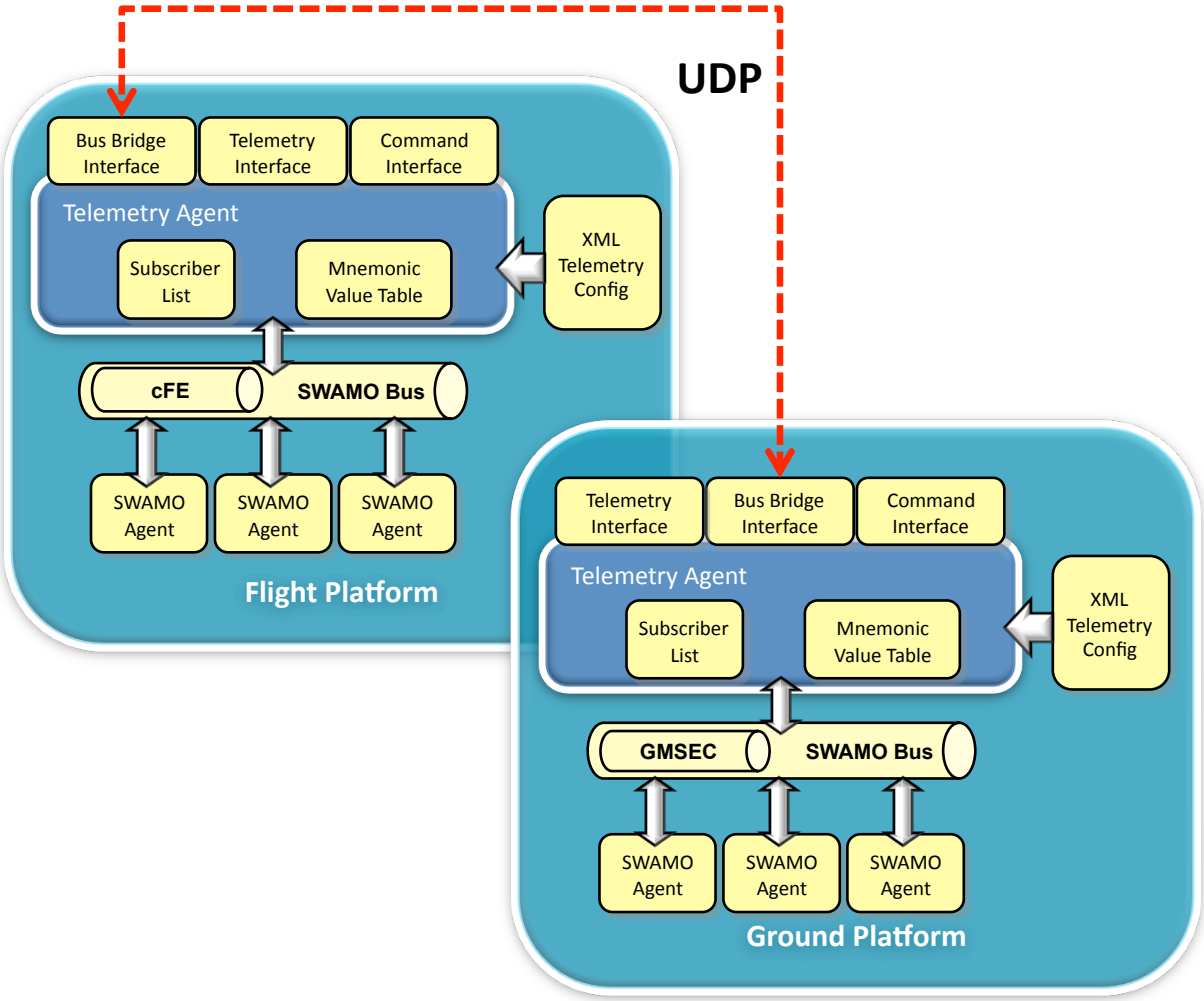


1. No Amp to Single Amp
2. Single Amp to Dual Amp
3. Dual Amp to Single Amp
4. Single Amp to No Amp
5. No Amp to Dual Amp
6. Dual Amp to No Amp

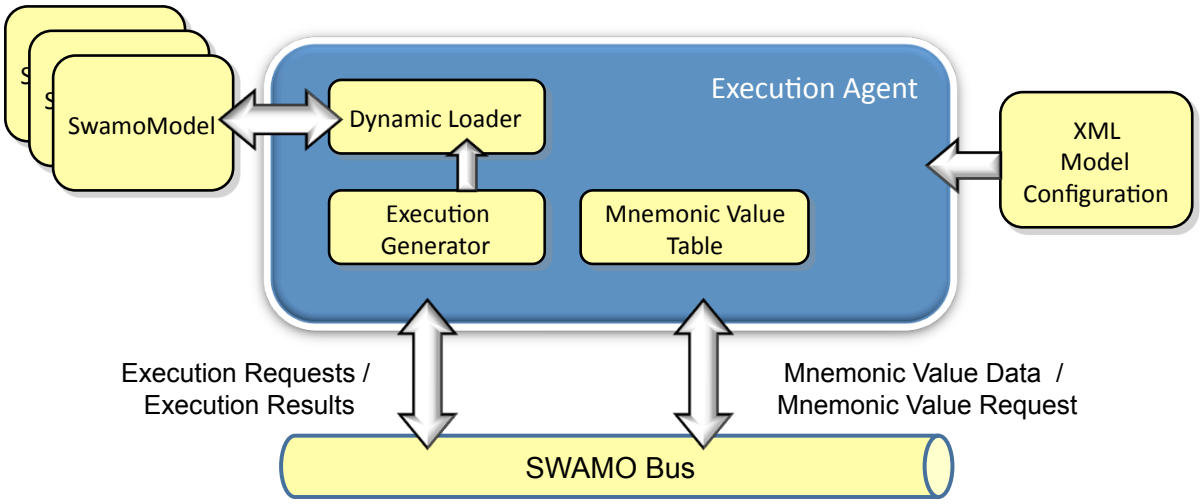
- MidSTAR has a power positive problem and will overheat unless batteries are discharged
- Initial MidSTAR Power model was developed with the help of the MidSTAR team
- Current model is a state machine based on battery voltages [normal, medium, high]
  - Normal voltages have neither onboard power amplifier turned on
  - When in medium state, one power amp is turned on (alternating which one)
  - When in high state both power amps are turned on
  - If either medium or high state is exited both amps are turned off – normal state
- This base model will be enhanced to more closely control MidSTAR battery temperatures based on predicted solar illumination

Telemetry Agent

- Provides access to platform telemetry interface
- Configurable interface type and mnemonic list
- Provides request/reply mnemonic data to agents
- Designed to add additional interfaces based on mission telemetry format



Execution Agent



- All SWAMO models have a standard interface and are encapsulated by the Execution Agent
- Models can be configured to run in Real-time mode or in Predictive mode
- The Execution Agents are configured via XML as to what models to load, what mnemonics are required, and what mode to operate in
- Accepts requests to execute “Predictive” models, then publishes results to requestor
- Requests mnemonic value data stream for all models listed in the configuration file
- Real-time models are constantly updated with telemetry and results published as they occur